13. Potential Effects of Evaporative Concentration in Pit Lakes and/or Contaminant Movement to Ground Water

LIMNOLOGY OF THE SLEEPER PIT LAKE, HUMBOLDT COUNTY, NEVADA
Atkin, S.A. (Water Management Consultants, Inc., Denver, CO); W.D. Schrand (Nevada Gold Mining, Inc., Winnemucca, NV)
Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 347-358, ©2000

Closure plans for open pit mines require the prediction of final pit lake water chemistry. The geochemical models used for water quality predictions make assumptions about the physical and chemical behavior of the water in the lake; however, a few pit lakes have been well documented to provide empirical data for model design. The pit lake at the Sleeper mine has been characterized with regular water chemical analyses and regular, continuous, multi-parameter profiles through the water column. The lake has undergone repeated periods of chemical and thermal stratification.

GEOCHEMICAL MODELING OF MINE PIT WATER AN OVERVIEW AND APPLICATION OF COMPUTER CODES
Bird, David A., Univ. of Nevada
EPA 530-R-95-012, NTIS: PB95-191250. 192 pp, 1993

This study evaluates the suitability of the hydrogeochemical computer modeling codes balance, MINTEQA2, PHREEQE, WATEQF, and WATEQ4 to the task of modeling post-mining pit water geochemistry. The advantages and disadvantages of these codes are discussed and considered in regard to their utility for pit water modeling. The report provides detailed descriptions of the operation of each software code. Chapter 2 contains a detailed discussion of introductory aqueous geochemistry and how the concepts are integrated into chemical models. Data from the Cortez mine, a carbonate-hosted, open pit, precious metal mine in Nevada, are used in an inverse model to determine geochemical mass transfer that has occurred between the mine wallrock and the pit lake. These results guide the development of a forward reaction path model that may be used for future mine sites.

CHEMICAL CHARACTERISTICS OF WATER AND SEDIMENT IN ACID MINING LAKES OF THE LUSATIAN LIGNITE DISTRICT
Friese, K.; M. Hupfer; M. Schultze
Acidic Mining Lakes: Acid Mine Drainage, Limnology, and Reclamation
Springer, New York. ISBN: 354063486X. p 25-46, c1998

NATURAL AND ANTHROPOGENIC SULFURIC ACIDIFICATION OF LAKES
Geller, W.; H. Klapper; M. Schultze
Acidic Mining Lakes: Acid Mine Drainage, Limnology, and Reclamation
Springer, New York. ISBN: 354063486X. p 3-24, c1998

GEOCHEMICAL MODEL OF WATER QUALITY IN PIT LAKE IN OXIDIZED TUFF. MCDONALD GOLD MINE: MODEL OF POST CLOSURE PIT LAKE CHEMISTRY

Johnson, Kathryn O., Johnson Environmental Concepts, Rapid City, SD

Draft Revison 1, Oct 1996

This report is a part of the technical review conducted prior to preparation of the Environmental Impact Statement for the application submitted by Seven-Up Pete Joint Venture (Applicant) for the McDonald Gold Mine. The report contains a comparison of the geochemical pit lake model conducted by the Applicant and presents an alternative geochemical pit lake model. The primary differences in the assumptions and input between the two models are: 1) slightly different chemical compositions of the various water types input to the model; and 2) the alternative model assumes a stratified lake with anoxic conditions in the lower depths. Both models use PHREEQE for mixing the inputs and MINTEQA2 for modeling precipitation and adsorption reactions. Sensitivity analysis in the Applicant's model was done by stochastic modeling of the input flow rates and trace metal concentrations. Sensitivity of the alternative model was evaluated by rerunning the models, assuming variations in the input from tuff groundwater. The alternative geochemical pit lake model predicts that the concentrations of arsenic, manganese, and zinc may exceed the lowest pertinent water quality standards. Under oxygenated conditions in the upper portion of the lake, zinc will likely exceed the standard; whereas, concentrations of arsenic and manganese will be less than the water quality standards. Under anoxic conditions zinc concentrations are predicted to be greater than the standard, manganese concentrations are predicted to be at or slightly greater than the standard, and arsenic concentrations may exceed the standard depending upon the concentration of arsenic in tuff groundwater and the proportion of tuff groundwater flowing into the pit lake. Comparison of the alternative pit lake model presented in this report with the Applicant's model shows that: 1) the predicted concentrations of arsenic in both models exceed the water quality standards at the upper end of the range of uncertainly evaluated; 2) the alternative model predicts slightly greater concentrations of manganese which may exceed the water quality standard; and 3) the alternative model predicts greater concentrations of zinc which exceed the water quality standard throughout the lake.

This report is available at http://johnsonenviro.com/pitlake.htm

CURRENT SEASONAL LIMNOLOGY OF THE BERKELEY PIT-LAKE

Jonas, J., Univ. of Montana, Butte, MT

Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 359-366, ©2000

The Berkeley pit-lake was sampled during two seasons, fall 1997 and spring 1998, from the surface to the bottom. Various parameters were measured to determine what effect the seasons had on the water column. It was determined that a seasonal turnover did occur between the fall and the spring sampling; however, the depth of mixing due to turnover could not be established. Trends were observed which suggested that microbial activity was altering the iron speciation at depth, and subsequently masking the extent of mixing. Various trace metals were removed from the surface water by either co-precipitation with schwertmannite or adsorption.

WATER PHYSICAL-CHEMICAL CHANGES IN A FORC-FLOODED PIT LAKE: A MULTIVARIATE ANALYSIS

Kalin, M.; Y. Cao; M. Smith, Boojum Research, Ltd., Toronto, ON

North American Benthological Society Annual meeting, Duluth, 1999

An open pit with a surface area of 24 ha and the maximum depth of 50m in Northern Saskatchewan was flooded using natural lake water in early 1992. Since then, water samples have been collected from the artificial lake at 5m intervals over the depth, basically three times per year. A total of 213 sample An open pit with a surface area of 24 ha and the maximum depth of 50m in Northern Saskatchewan was flooded using natural lake water in early 1992. Since then, water samples have been collected from this artificial lake at 5m intervals over the depth, basically three times per year. A total of 213 samples are available with over thirty water quality parameters measured. This provides a unique opportunity to examine the temporal and spatial changes of water physics and chemistry at the early stage of an aquatic system. Seventeen major water physical and chemical variables were chosen for a Principal Component Analysis (PCA). The data were standardized to 0 mean and 1 variance before the analysis. Three trends were recognized: 1) Axis 1, 2 and 4 are significantly correlated to the number of days (since the first sampling), temperature (a measure of seasons at the study area) and depths, respectively. Total Suspended Solid, Fe, Dissolved Oxygen and Phosphorus decreased over time while most elements (e.g., Mg, Ca, K, Na), Total Organic Carbon and HCO3 increased. Two metal contaminants, Arsenic and Nickel, deceased since 1996, particularly in summer. These water chemical-physical changes were attributed to interactions between physical-chemical and biological processes.

LIMNOLOGICAL FUNDAMENTS OF ACID MINING LAKES

Kalin, M.; W. Geller

Acidic Mining Lakes: Acid Mine Drainage, Limnology, and Reclamation
Springer, New York. ISBN: 354063486X. p 423-426, c1998

WALL ROCK MINERALOGY AND GEOCHEMISTRY OF DEXTER PIT, ELKO COUNTY, NEVADA

Lengke, M.F. (Univ. of Nevada, Reno, NV); R.N. Tempel; L.L. Stillings (U.S. Geological Survey, Reno, NV); L.S. Balistrieri (U.S. Geological Survey, Seattle, WA)

Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 319-326, ©2000

The Dexter pit lake, within the Tuscarora volcanic field in Elko County, Nevada, formed after closure of the Dexter mine. Mineralogy at the Dexter mine is related to widespread feldspar, silica, and chlorite alteration. Major mineralogy includes quartz, alkali feldspar, albite, phlogopite-biotite, hornblende, iron-titanium oxide, chlorite, kaolinite, smectite, illite, and sericite, with lesser amounts of calcite, zircon, apatite, and rutile. Trace element geochemistry is characterized by high levels of As, Ba Cr, Cu, V, Zn, B, Zr, Li, and U. Detailed mineralogy and geochemistry are required for geochemical models to accurately predict trace element concentrations in pit lake waters.

THE REACTIVITY OF SULFUR-RICH SEDIMENTS IN LAKE JUNIN, PERU: THE IMPORTANCE OF PERMANENT SUBMERGENCE

Martin, A.J.; J.J. McNee (Larox Environmental Services Ltd., Vancouver, BC); T.F. Pedersen (Univ. of British Columbia, Vancouver, BC)

Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 143-150, ©2000

Field sampling was conducted in Lake Junin, Peru, in order to assess the post-depositional reactivity of the highly contaminated lake sediments. High resolution profiles of dissolved Fe, Mn, SO42- and H2S across the sediment-water interface illustrate that the organic-rich sediments in the main basin become anoxic within several millimetres of the sediment-water interface. These permanently submerged deposits in the main basin serve as a diffusive sink for dissolved Zn and Cu. Conversely, the periodically unsaturated deposits in shallow areas are characterized by the remobilization of Zn and Cu in the deep acidic (pH<4) pore waters, resulting in the release of these metals to the overlying water column.

WATER QUALITY IN OPEN PIT PRECIOUS METAL MINES

Macdonald, M.S.; G.C. Miller; W.B. Lyons

EPA 530-R-95-011, NTIS: PB95-191243. 74 pp, Dec 1994

Open pit mining below the water table results in pit lakes. This study documents issues concerning pit water quality and determines where additional research is needed. The report discusses factors contributing to pit water quality: groundwater flow, water-wall rock reactions (flow in structures and sloughing of wallrocks), acid versus alkaline pit water (the acid forming process, neutralization, evaluation, of potential for acid production, and mitigation of acid mine drainage), trace elements, arsenic speciation, evapo-concentration, and hydrothermal activity.

INJECTED ARD PLUME BEHAVIOUR IN A PIT LAKE UTILIZING IN SITU DYE STUDIES

Muggli, D.L.; C.A. Pelletier; G.W. Poling (Rescan Environmental Services, Vancouver, BC) E.C. Schwamberger (BHP Copper, Tucson, AZ)

Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 305-318, ©2000

The Pit Lake at Island Copper has evolved into a 3-layered meromictic system. Acid Rock Drainage (ARD) is collected and injected into the lake at 220 meters depth via two diffuser systems. In situ dye studies were conducted during two differing hydrological regimes in order to determine the behavior of the ARD plume within the Pit Lake. Results indicated that when runoff from the waste dumps was low, the injected ARD remained within the bottom half of the intermediate layer of the Pit Lake, initially below depths of 90 meters. However, when runoff from the waste dumps was high, the injected ARD at ~220 meters depth rose through the intermediate water column layer rapidly, but did not breach the top pycnocline at ~10 meters depth. Overall, the system is currently performing as a mixing bowl with a strong boundary or cap at the upper pycnocline, maintaining mixing below the 10 meter depth water level.

LIMNOLOGY OF EXTREMELY ACIDIC MINING LAKES IN LUSATIA (GERMANY) AND THEIR FATE BETWEEN ACIDITY AND EUTROPHICATION

Nixdorf, B.; D. Lessmann; U. Gruenewald; W. Uhlmann
Brandenburg Technical Univ. of Cottbus, Bad Saarow (Germany). Environmental Sciences and Process Engineering

Fourth International Conference on Acid Rock Drainage, 31 May-6 June 1997, Vancouver, Canada
CANMET, Natural Resources Canada, Ottawa, ON (Canada). Vol 4, p 1745-1760, 1997

The research estimated the development of water quality in geogenically acidified lakes under various flooding regimes and the success of neutralization methods. The study examines the chemistry and biology of 30 lakes resulting from surface lignite mining. Study sites, chemical and biological classification of mining lakes in Lusatia, trophic conditions and phytoplankton development, and the limnological potential of acidified lakes and the risk of excess eutrophication due to phosphorus loading are discussed.

THE ACID LAKES OF LIGNITE MINING DISTRICT OF THE FORMER GERMAN DEMOCRATIC REPUBLIC

Reuther, Rudolf (ed.)

Geochemical Approaches to Environmental Engineering of Metals
Springer, New York. ISBN: 0387588485. Chapter 8, c1996

EVOLUTION OF THE MCLAUGHLIN GOLD MINE PIT LAKES, CALIFORNIA

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Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 367-377, ©2000

Cessation of open pit mining in 1996 at the McLaughlin hot-spring type gold deposit has resulted in the development of two pit lakes. The south pit lake developed from alkaline ground water infiltration and had an initial pH of 7.2. It contained high concentrations of boron and chloride. Numerous carbon dioxide gas vents were initially present, but as the pit lake increased in depth, gas venting ceased. A chemocline occurs at a depth of 47 m. The upper layer of the lake has lower pH, temperature, and conductivity than the lower layer. Effluent from ore and waste rock piles directed into the south pit lake has contributed to high levels of antimony, arsenic, cobalt, copper, mercury, nickel, and zinc. Iron oxyhydroxide is abundant in mine effluent that enters the pit lake and adsorption onto this phase has lowered the arsenic and antimony concentrations. The acidic water, pH 4.56, initially had high concentrations of cobalt, mercury, and nickel. Buffering by wall rocks has established a slightly alkaline pH of 7.62.

EVAPORATIVE CONCENTRATION IN PIT LAKES: EXAMPLE CALCULATIONS FOR THE GETCHELL PIT LAKES, NEVADA

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Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 337-346, ©2000

Three pits at the Getchell mine contained water during a hiatus in mining activity (1968-1983). For this period, expected concentrations of As, C1, SO4, and TDS resulting solely from evaporative concentration were computed. Computed values are 1.6 to 2.3 times greater than those measured in local groundwaters. However, computed values for As, SO4, and TDS are lower than measured values in the pit lakes. In some cases, the computed values are only 8% of the measured pit lake values, indicating a major control on water quality via water-rock interactions. In contrast, computed C1 values exceed measured pit lake concentrations.

GEOCHEMICAL MODELING METHODS OF PREDICTING TRACE ELEMENT CONCENTRATIONS IN DEXTER PIT LAKE, ELKO COUNTY, NEVADA

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Fifth International Conference on Acid Rock Drainage, 20-26 May 2000, Denver, CO
Society for Mining, Metallurgy, and Exploration, Inc. (SME), Littleton, CO. ISBN: 0-87335-182-7. Vol 1, p 327-336, ©2000

Dexter pit lake, within the townsite of Tuscarora, NV, has been in existence since 1990 and provides a natural laboratory for the study of cycles of trace elements associated with ore deposits (e.g. As, Cu, Pb, and Se). The goal in this study is to develop and calibrate methods of geochemical modeling that may be applied to estimating the concentrations and fluxes of trace elements in pit lake systems. The initial modeling work considers limnology, hydrology, wall rock mineralogy and geochemistry, benthic fluxes, and colloid composition. Results from the work may be useful in evaluating water quality in the arid West.